Astronomy 330

This class (Lecture 18):
Origin of Intelligence

Next Class:

Cultural Evolution

Extra credit paper due tomorrow!

HW #8 due Sunday.

Music: *Intelligent Guy*– Butthole Surfers

Question

How was your Spring Break?

a) Good
b) Bad
c) Better than you thought it would be.
d) Worse than you thought it would be.
e) You missed me horribly. (xoxoxoxo :p)

Question

How is the class going so far?

a) Perfect
b) Good.
c) Bad.
d) Okay.
e) I don't want to answer this on iclicker.

Exam 2

- Exam 2 is coming up– April 9th!
- Will be similar to Exam 1.
- Cover from last exam up to Thursday's lecture.
- Again, 1 sheet of notes will be allowed.

Question

How many multiple choice questions do you want on Exam 2 (Exam 1 was 40)?

a) 30
b) 35
c) 38
d) 40
e) 45

Paper Rough Draft

- Worth 1% of your grade, but really worth more.
- Due on or before April 22nd! (Hard date!)
- Should pretty much be the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, **proper citation**, and general style.
- 5 to 8 pages double-spaced 12-point font, not including references.
- ***Mars is a planet without an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 20007).***
  - ***I expect to see a few refs per page!***

Outline

- Along comes oxygen!
- Development of intelligence.
- Brains. Brains.
- The rise of the primates!

Drake Equation

That's 1.4 life systems/decade

Frank Drake

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	20 stars/ yr	0.12 systems/ star	1.25 x 0.12 = 0.15 planets/ system	0.4 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Early Earth

- We've talked about the Early Earth's atmosphere– mostly N and CO_2, which dominated the atmosphere for the first 3 billion years!
- But life was polluting the planet even then.

Making Oxygen!

- The early prokaryotes played a crucial role for life on Earth by producing oxygen through photosynthesis.
- Cyanobacteria (also called blue-green algae) changed the world!
- Lived in colonies that formed mats or films, growing into large structures called stromatolites.
- Still around, but much more common before 700 Myrs ago.

Making Oxygen!

- About 2 billion years ago atmosphere became oxygenated!
- Probably killed off many species.
- But, oxygen was new and important step in intelligence
- It allowed a new energy extraction method
  - Aerobic (using oxygen) metabolism
  - More complex life
  - Created ozone layer (dry land now an option for life on Earth!)

Relationship to ETs

- Would evolution on other planets have a similar time-scale?
- Evolution is not a deterministic process.
- Selection seems to be mostly luck, rather than adaptation.
- On the other hand, many traits have developed in several lineages– warm blood and eyes.
- Some say that intelligence seems to increase in many lineages, so it is likely that if live exists then intelligent life exists.
- On the other hand, the plant kingdom never developed neurons.

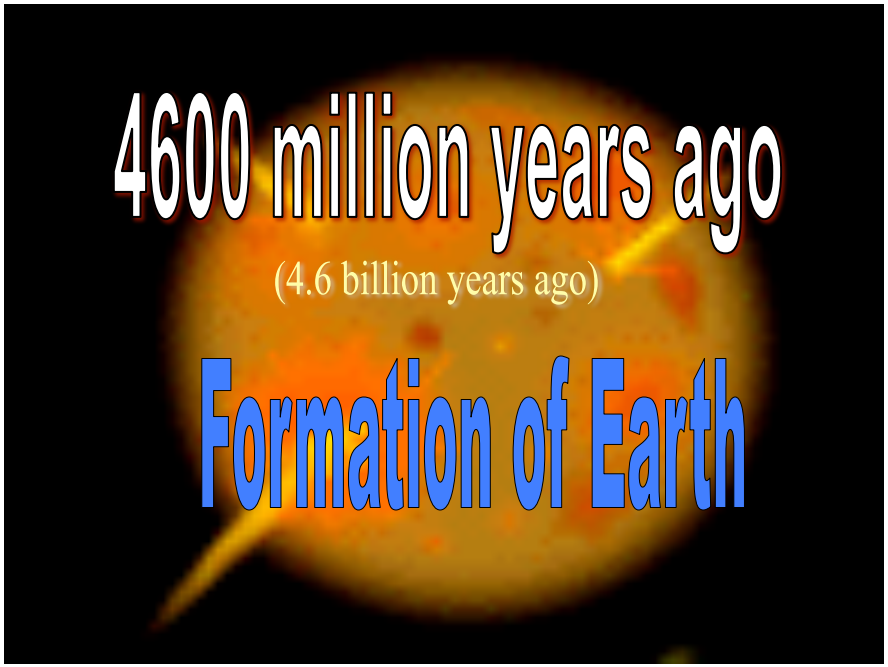
Question

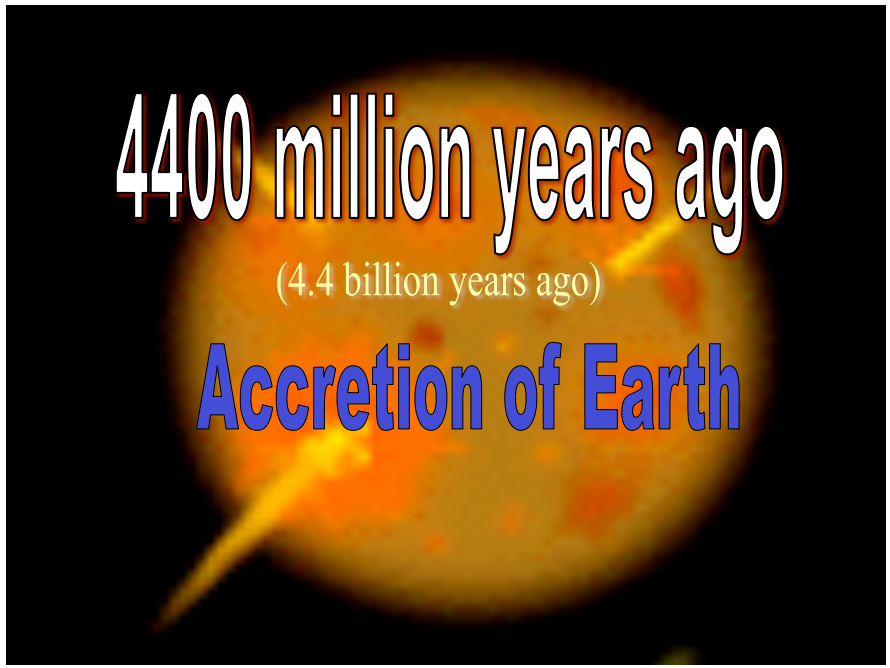
The Early Earth's oxygen in our atmosphere came from

a) trees.
b) colonies of cyanobacteria.
c) comets.
d) colonies of plankton.
e) outer space.

Summary

- This following slides are from: http://www.udayton.edu/~INSS/
- Nice timeline of life on Earth.

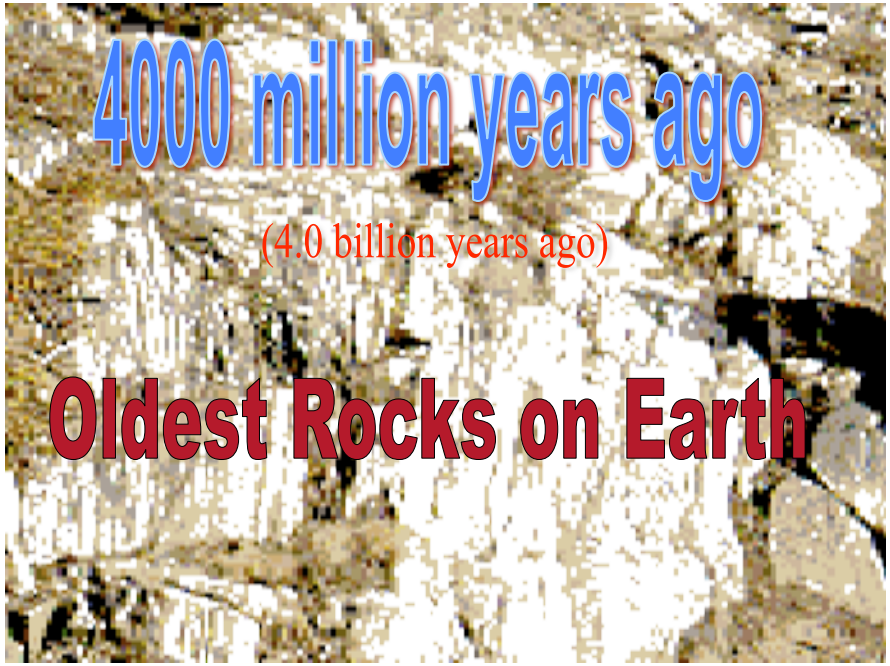


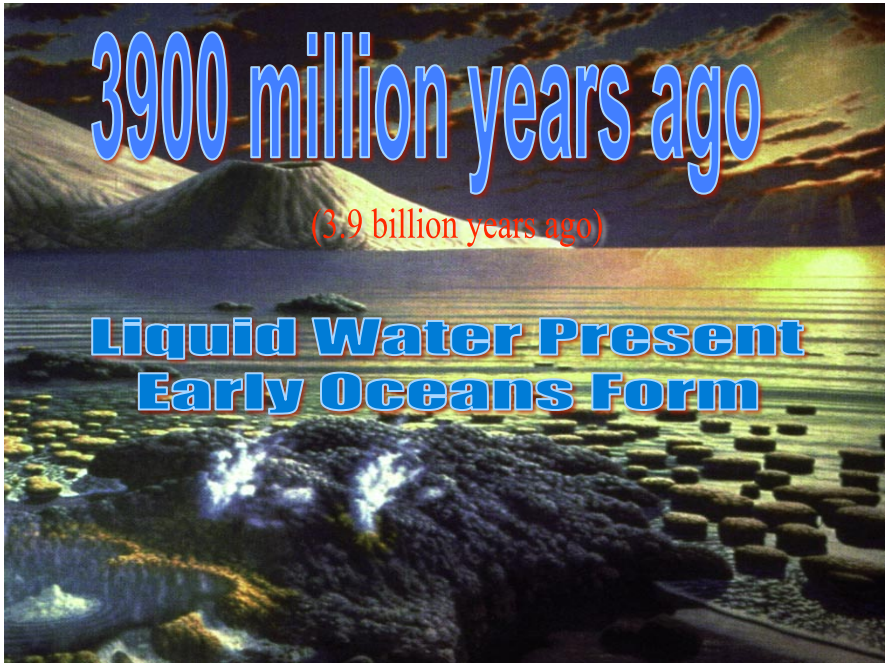

4400 million years ago
(4.4 billion years ago)
Accretion of Earth


4300 million years ago
(4.3 billion years ago)
Iron Catastrophe
Earth separates into layers


4200 million years ago
(4.2 billion years ago)
Early Atmosphere
No Life


4100 million years ago
(4.1 billion years ago)
Early Atmosphere
No Life


4000 million years ago
(4.0 billion years ago)
Oldest Rocks on Earth


3900 million years ago
(3.9 billion years ago)
Liquid Water Present
Early Oceans Form


3800 million years ago
(3.8 billion years ago)
First Bacteria
(Prokaryotic)


3700 million years ago
(3.7 billion years ago)
Bacteria


3600 million years ago
(3.6 billion years ago)
Bacteria

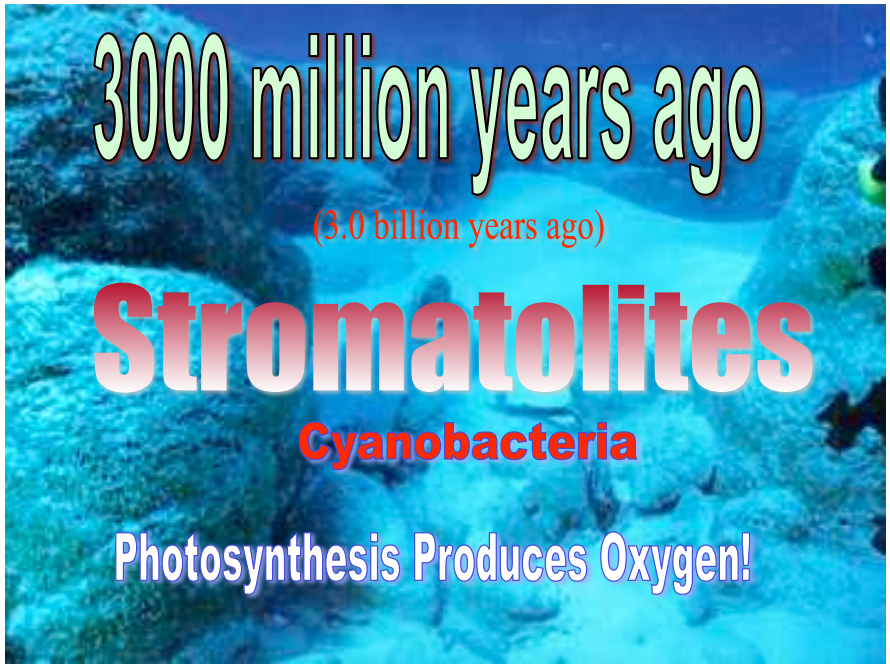

3500 million years ago
(3.5 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!


3400 million years ago
(3.4 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!

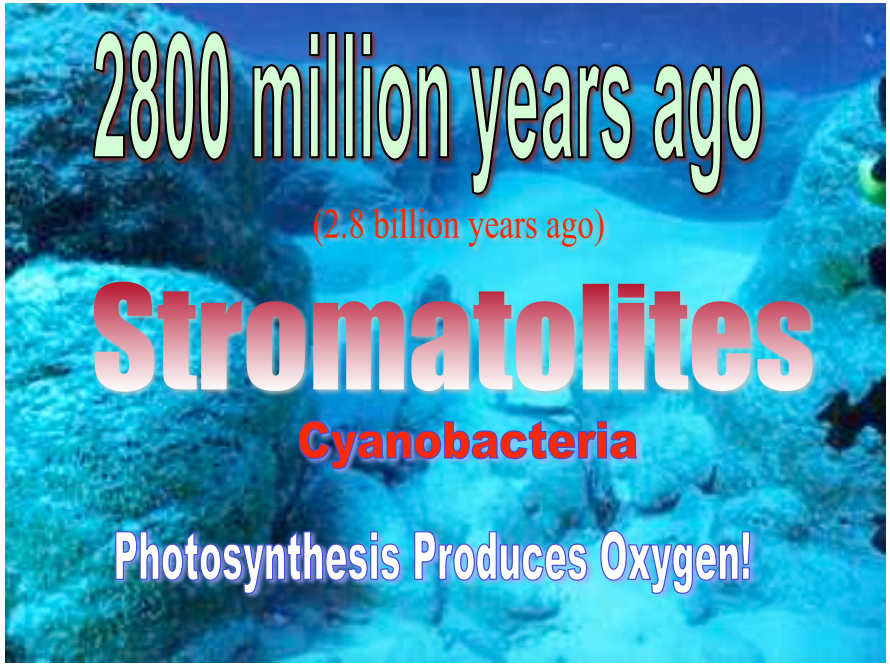

3300 million years ago
(3.3 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!


3200 million years ago
(3.2 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!

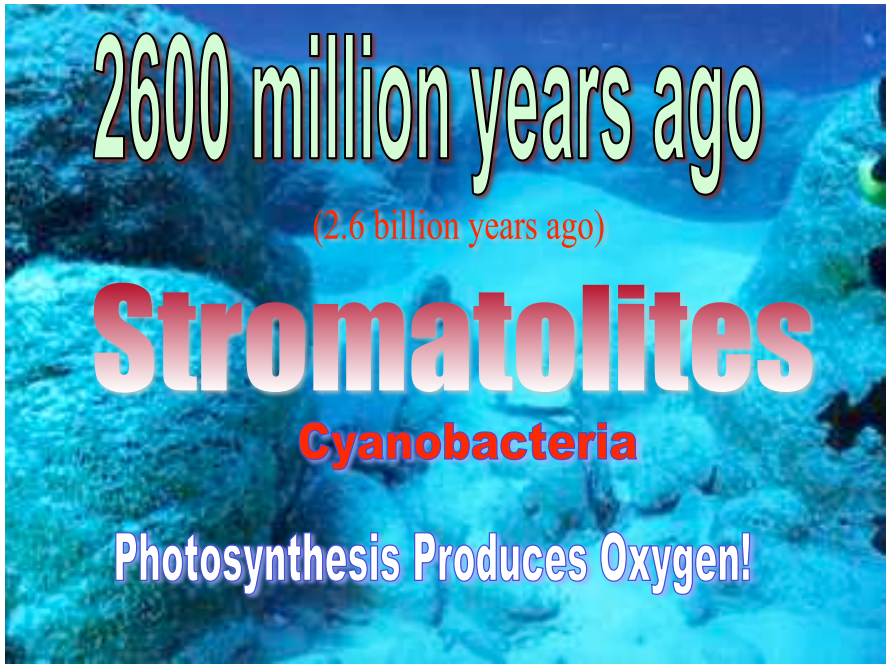

3100 million years ago
(3.1 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

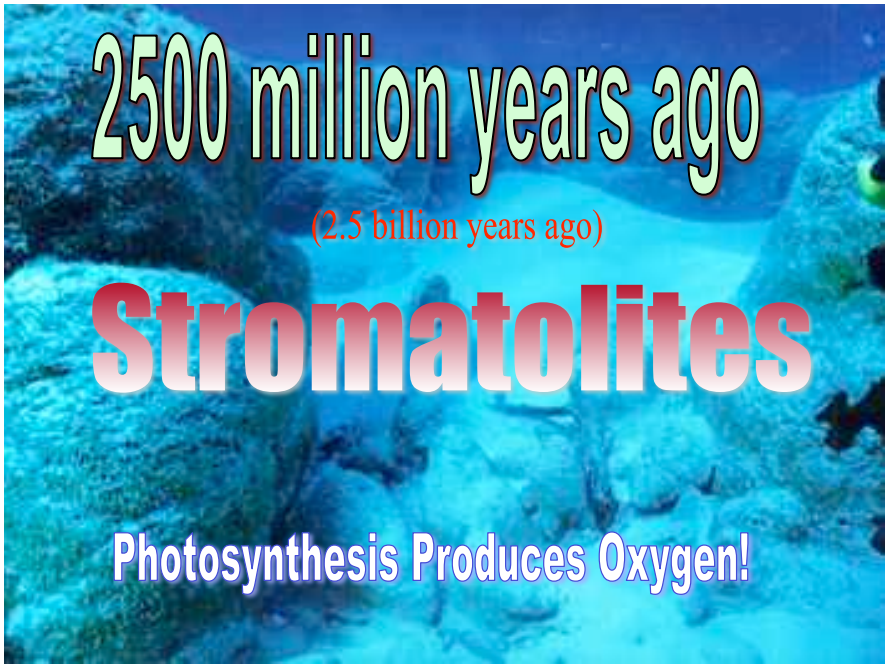

3000 million years ago
(3.0 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

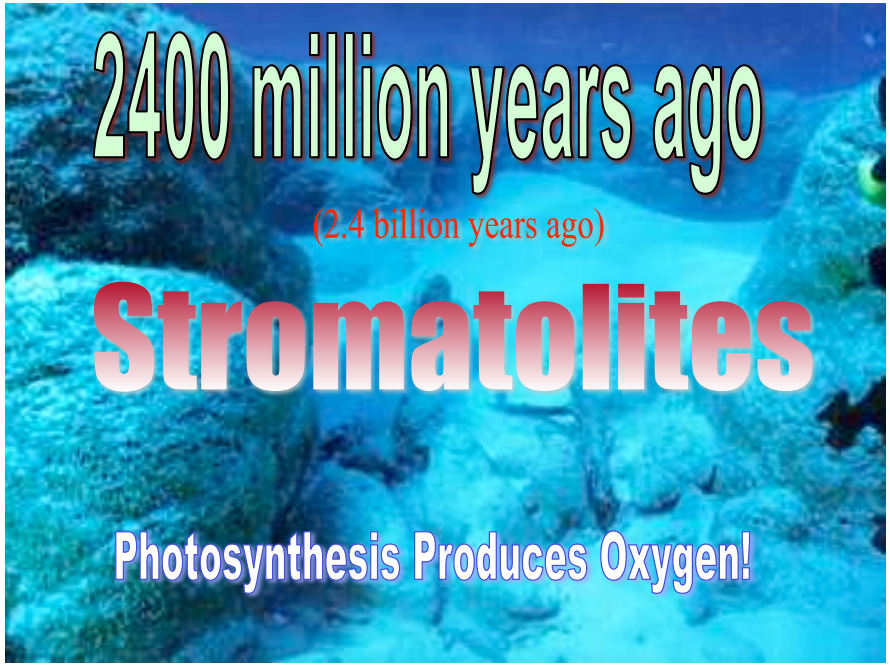

2900 million years ago
(2.9 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

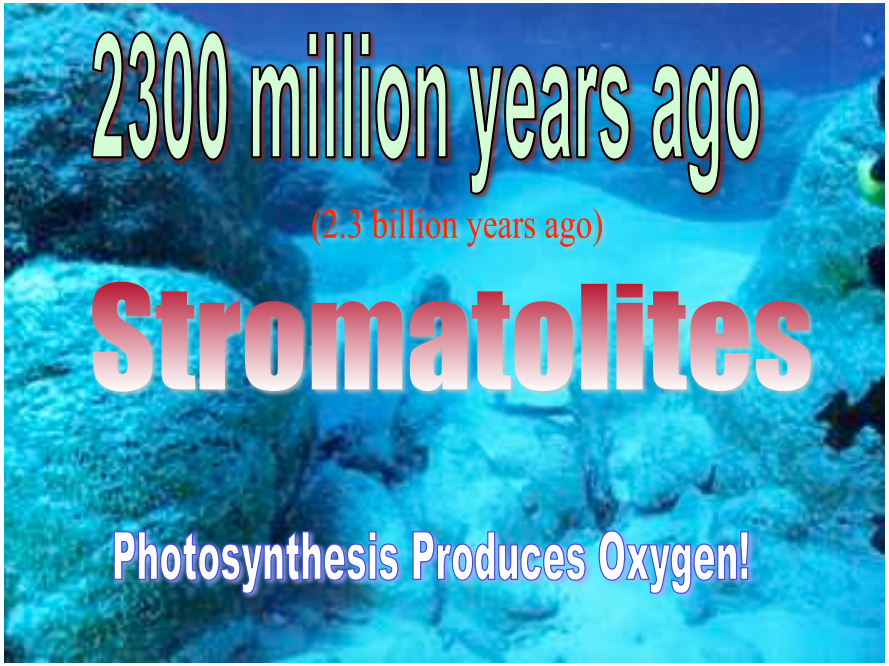

2800 million years ago
(2.8 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!


2700 million years ago
(2.7 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!


2600 million years ago
(2.6 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!


2500 million years ago
(2.5 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2400 million years ago
(2.4 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2300 million years ago
(2.3 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2200 million years ago
(2.2 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2100 million years ago
(2.1 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!

2000 million years ago

(2.0 billion years ago)

Beginning of Oxygenated Atmosphere

First Pollution Crisis!

Redbeds

Evidence of significant free oxygen

1900 million years ago

(1.9 billion years ago)

Oxygenated Atmosphere

Cyanobacteria still producing oxygen!

1800 million years ago

(1.8 billion years ago)

Oxygenated Atmosphere

Cyanobacteria still producing oxygen!

1600 million years ago

(1.6 billion years ago)

Single-celled Eukaryotes

Still Present:


1500 million years ago
(1.5 billion years ago)
Single-celled Eukaryotes
Still Present:


1400 million years ago
(1.4 billion years ago)
Single-celled Eukaryotes
Still Present:


1300 million years ago
(1.3 billion years ago)
Single-celled Eukaryotes
Still Present:

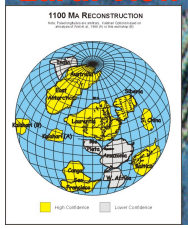

1200 million years ago
(1.2 billion years ago)
Single-celled Eukaryotes
Still Present:

1100 million years ago

(1.1 billion years ago)

Single-celled Eukaryotes

Earth View



Still Present:

1000 million years ago

(1.0 billion years ago)

Multicellular Organisms Appear

Marine Invertebrates

Soft Bodies

900 million years ago

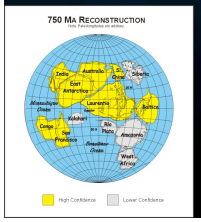
Marine Invertebrates Flourish

Still Present:

800 million years ago

Marine Invertebrates Flourish

Earth View

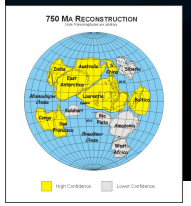


Still Present:

700 million years ago

Marine Invertebrates Flourish

Earth View



Still Present:

600 million years ago

Ediacara Fauna

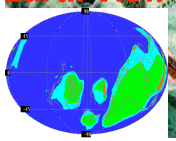
Earth View

Still Present:

500 million years ago

543 mya
First Hard Parts
(Shells & Bones)
First Primitive Fish

Earth View



Life Migrates to Land
470 mya

438 million years ago

Mass Extinction

400 million years ago

Most life still underwater

First Seed Plants

First Amphibians

Still Present:

367 million years ago

Mass Extinction

300 million years ago

Vast Coal Swamps on Land

Origin of Many Animals

amphibians, sharks, reptiles, insects

Earth View

Pangea: "All lands". The face of the Earth has changed through time. 295 million years ago most of the world's landmasses were linked into one 'supercontinent' called Pangea. ISU's Paleomagnetics lab studies the past movement of continents.

245 million years ago

Mass Extinction

90 % of all species perish

Earth View

PERMIAN
225 million years ago

200 million years ago

Age of the Dinosaurs and Reptiles

Plant Life: Ferns & Gymnosperms

First mammals

Earth View

TRIASSIC
200 million years ago

Still Present:

100 million years ago

First birds

First Placental Mammals

First Flowering Plants

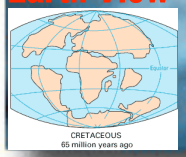
Still Present:

65 million years ago

Mass Extinction

Extinction of the dinosaurs and others

Earth View



CRETACEOUS
65 million years ago

65 million years ago to Present Day (0 mya)

Dominance of flowering plants, insects mammals, and birds

Humans 5 mya

Earth View

PRESENT DAY

Still Present:

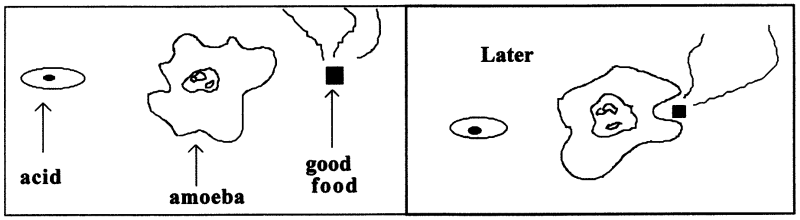
Picture Credits

Smithsonian Institute
Field Museum
NASA
University of California, Berkeley Museum
http://rainbow.ldeo.columbia.edu/courses/v1001/7.html
http://www.geol.umd.edu/~kaufman/ppt/chapter3/sld019.htm
http://www.uta.edu/geology/geol1425earth_system/images/gaia_chapter_11/ArcheanLandscape.jpg
http://www.uta.edu/geology/geol1425earth_system/1425chap11.html
http://www.geol.umd.edu/~kaufman/ppt/chapter3/sld019.htm
http://www.exhibits.lsa.umich.edu/Exhibits/Anthropology/Diaramas/Nat.Am./Copper/Copper.html

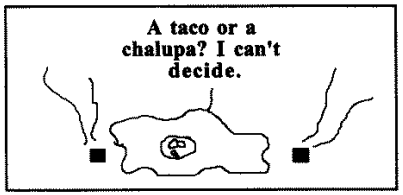
Evolution of Intelligence

- Through diversity, evolution has resulted in an increase in the complexity of organisms on Earth.
- Can we associate complexity with intelligence?
- If intelligence is an advantageous trait, it is plausible that intelligence would increase over time.
- But, what is intelligence?

An Amoeba Distinguishes

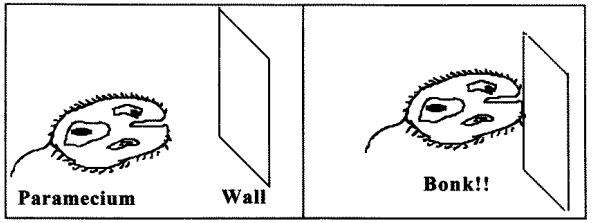


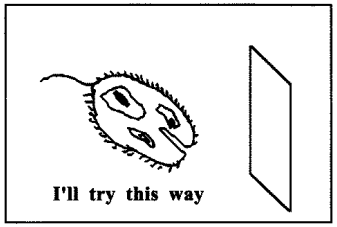
- Has a model of its environment.
- What if two pieces of food are placed nearby?



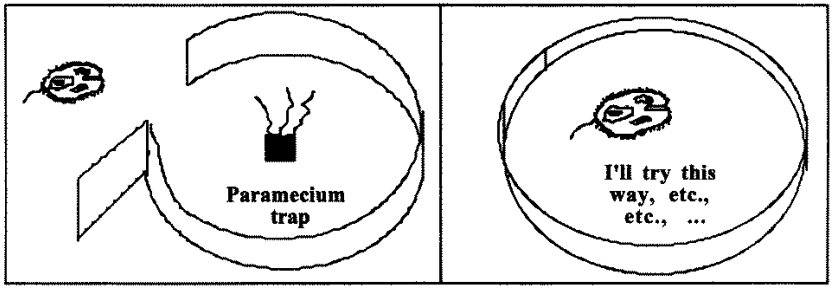
The Intelligent Paramecium?

- Still one celled, but more complex.
- Has a kind of primitive memory.





Intelligence Breakdown



- Doesn't realize to give up.
- Smarter than the amoeba, but no genius.
- With complexity does come some intelligence.
- There seems to be a continuum of intelligence.

Evolution of Intelligence

- A general definition is "the ability to model the world, including the organism's own self".
- But even single-celled animals seem to be able to do that to some degree.
- Can think of intelligence as a continuum, not a unique aspect of humans.
- Why then, does there seem to be a gap between us and the rest of life on Earth?

Origin of Human Intelligence

- If we view intelligence as a continuum, then we are not essentially different than other organisms.
- Still need a quantitative measure of intelligence.
- Intelligence could be defined by the amount of information stored in the organism. DNA storage.

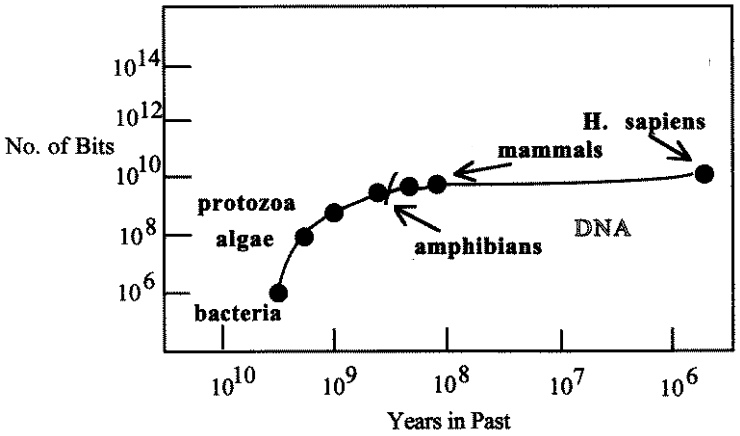
Spottet Dolphins sounds
http://neptune.atlantis-intl.com/dolphins/sounds.html

DNA Storage

- We'll use bits of information
  - Yes = 1
  - No = 0
- Each DNA base has 2 bits of information– 4 options.
- Each codon has 3 bases or 6 bits (3 x 2)
- Humans have (3 x 10^9) bases x 2 bits per base = 6 x 10^9 bits (~750 Mbytes), like 4000 books of 500 pages.

Spottet Dolphins sounds
http://neptune.atlantis-intl.com/dolphins/sounds.html

Development of Intelligence



Caveats

- Existence of large amount of "junk DNA" makes it problematic to measure intelligence by number of DNA possibilities
  - Only about 2% of human DNA seems to actually code proteins, then humans have 1.2 x 10^8 bits (15 MB), or 800 books
  - For some organism the "junk DNA" is significant: Newts and lilies would have more than 10^{11} bits (12.5 GB).


http://www.eeingeorgia.org/eic/images/landfill.jpg

Caveats

- Keep in mind that less intelligent organism did not disappear, so there is **no trend** for organisms to get smarter.
- The **diversity** of life with time led to **some** species with intelligence.


http://www.eeingeorgia.org/eic/images/landfill.jpg

Limited Pockets in Genes

- There are limits to how much info genes can store.
- If you try to store too much info, mutations can wipe you out.
- For eukaryotes, the error rate is about 10^{-9}, limiting the amount of storage to about 10^{10} bits.

Limited Pockets in Genes

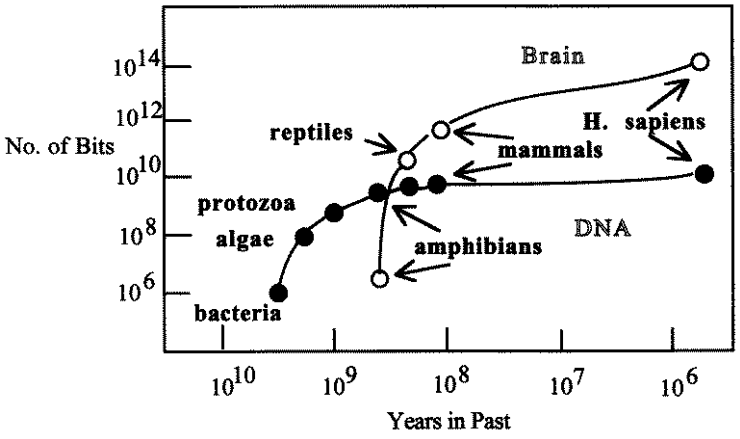
- What did life do?
- Evolution devised a new way (extra-genetic) to store information.
- Life developed a nervous system and brains. More bits of storage that are R/W. We can learn!

Info Storage in Brains?

- Information storage in DNA is straightforward, but in the brain?
- There are 10^{11} nerve cells (called neurons) in a human brain, but they do not work in binary form, more analog-based.
- And they are interconnected– a neuron can be connected (with synapses) to 10^3 other neurons.

- An impulse triggers a chain of neurons to "fire" causing a reaction. So, really the information is stored in synapses. $10^{11} \times 10^3 = 10^{14}$ bits (12.5 Terabytes)

Development of Intelligence



Intelligence

- It seems that intelligence is a desirable trait.
- And we can argue for a rough connection between the rise of complexity and intelligence.
- Increased genetic diversity is the key With more organisms of all types, a more intelligent species is reasonable.

http://www.cartoonstock.com/lowres/shr0945l.jpg

Intelligence

- Still, the point of the Drake equation is to find civilizations with which to communicate, so we need to think about developing human-like or better, intelligence.

http://www.newenglandfilm.com/news/archives/03march/reviews.htm

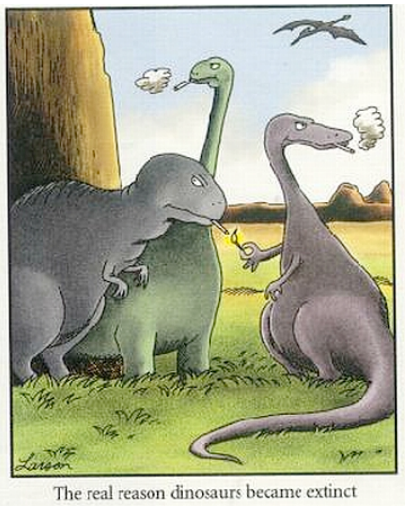
Human-Level Intelligence

- Our species is the only one on Earth to have developed a technological civilization.
- How likely is that to happen on other planets?

Human-Level Intelligence

- Actually the development of humans is still controversial, even among anthropologists. New fossils are appearing that change our understanding.
- Mammals first appeared on the fossil stage about 200 Myrs ago, but were minor players until about 65 Myrs ago.

Less Credible Theories



The real reason dinosaurs became extinct

http://www.boundaryschools.com/fws/snidsmk.htm

Primates

- Main characteristics:
  - Flat fingernails
  - Eyes in front of face
  - No sharp teeth or claws
  - Some have large brain-to-body rations, but most do not.
  - Primarily adapted to life in trees

http://saldf.stanford.edu/Projects.htm

Primates

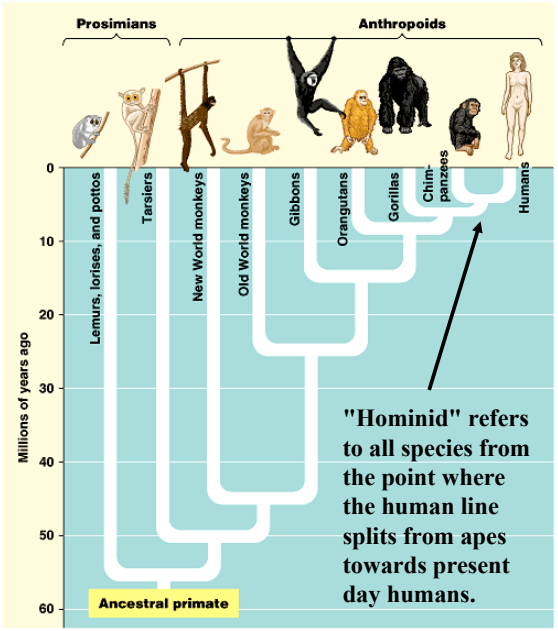
- Basically, with **one** large exception, primates have not been very successful.

That one

Not that one

Family Tree?

- General trend of adaptation to tree life.
- From toe claws to gripping with large toes or fingers (thumbs).
  - This allowed for tool use.
- From nocturnal to daylight.
- More vision– a rounded face with forward eyes and color vision.
- These mutations were random.



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